Application No. 10/534,784
Amendment dated January 5, 2009
Reply to Office Action of October 3, 2008

Docket No.: NY-GRYN 220-US

AMENDMENTS TO THE CLAIMS

1-21. (Canceled)

22. (Previously presented) A method for producing hydrogen from a hydrocarbon with high energy efficiency while releasing very low or zero levels of carbon dioxide and pollutants, said method comprising the steps of:

preheating reagents comprising hydrocarbons, a nearly pure flow of oxygen and water to be vaporized;

oxidizing a portion of said hydrocarbons using the flow of nearly pure oxygen and converting nearly all of the remaining portion of said hydrocarbons into hydrogen, carbon monoxide and carbon dioxide by supplying heat and water vapor at suitable temperature, thereby improving the hydrogen production yield and forming a conversion product comprising a mixture of said hydrogen, said carbon monoxide, said carbon dioxide, and excess water vapor;

cooling said conversion product to recover a fraction of the thermal energy of said conversion product which can be used to preheat said reagents and condensing at least part of the water vapor contained in said conversion product;

extracting said hydrogen from said conversion product for consumption or storage for later consumption; and

wherein said steps of said method being performed at suitably high pressures above 30 bar to intensify the heat exchanges, promote the liquefaction of said carbon dioxide and the condensation of the water vapor by cooling, and/or improve the overall efficiency of said method.

23. (Previously presented) The method of claim 22, further comprising the step of converting said carbon monoxide in said conversion product into said carbon

dioxide to form a final conversion product containing only carbon dioxide and uncondensed water vapor.

24. (Previously presented) The method of claim 23, further comprising the steps of condensing said carbon dioxide and capturing said carbon dioxide in a liquid form.

25. (Previously presented) The method of claim 23, wherein the step of extracting hydrogen extracts hydrogen from said conversion product using a membrane that is selectively permeable to hydrogen; and further comprising the step of lowering the partial pressure of said hydrogen downstream from said permeable membrane by diluting the flow of permeated hydrogen in a flow of extraction gas, thereby facilitating the permeation of the hydrogen and recovery of pure hydrogen through condensation of said extraction gas.

26. (Previously presented) The method of claim 25, wherein the step of extracting is performed simultaneously with the step of converting to lower the partial pressure of said hydrogen during said step of converting, thereby promoting the conversion of said carbon monoxide into said carbon dioxide.

27. (Previously presented) The method of claim 26, wherein the step of converting further comprises the step of regulating the temperature by adjusting the flow rate and/or the temperature of said extraction gas.

28. (Previously presented) The method of claim 22, wherein said steps of preheating and cooling are performed in a recovery exchanger so that said reagents and said conversion product circulate continuously through said recovery exchanger.

29. (Previously presented) The method of claim 22, wherein said hydrogen extracted from said conversion product feeds a fuel cell running with air; and further comprising the step of reducing the pressure of said conversion product and/or said hydrogen being fed to said fuel cell.

30. (Previously presented) The method of claim 22, further comprising the step of using a hydrogen production method to generate a flow of said nearly pure oxygen by electrolysis, thereby reducing the cost of producing said nearly pure oxygen consumed in said method and increasing the overall production of said hydrogen.

31. (Previously presented) The method of claim 22, further comprising the step of using a nitrogen production method to generate a flow of said nearly pure oxygen, thereby reducing the cost of producing said nearly pure oxygen consumed in said method.

32. (Previously presented) Apparatus for producing hydrogen from a hydrocarbon with high energy efficiency while releasing very low to zero levels of carbon dioxide and pollutants, said apparatus comprising:

a reactor for converting hydrocarbons using water vapor at suitable temperature, said conversion reactor being supplied with nearly pure oxygen to oxidize a portion of said hydrocarbons and supplying heat to convert nearly all of the remaining portion of said hydrocarbons into hydrogen, carbon monoxide and carbon dioxide, thereby forming a conversion product comprising a mixture of said hydrogen, said carbon monoxide, said carbon dioxide and excess water vapor;

a heating device for preheating reagents comprising said hydrocarbons, said nearly pure flow of oxygen, and water to be vaporized;

at least one cooling heat exchanger for cooling said conversion product, for recycling a fraction of the thermal energy of said conversion product to preheat said reagents, and for condensing at least a part of the water vapor contained in said conversion product; and

a hydrogen recovery unit comprising an extraction element for extracting said hydrogen from said conversion product for consumption in a hydrogen-consuming device, or storage in a hydrogen reservoir for later consumption; and

wherein said first conversion reactor, said heating device, said heat exchanger, and said recovery unit operating at suitably high pressures above 30 bar to intensify the heat exchanges, increase the compactness of the method, promote the liquefaction of the carbon dioxide by cooling, promote the condensation of the water vapor by cooling, and/or improve the overall efficiency of the apparatus.

33. (Previously presented) The apparatus of claim 32, further comprising at least one final conversion reactor operating with said hydrogen recovery unit for converting said carbon monoxide in said conversion product into carbon dioxide to form a final conversion product containing only carbon dioxide and uncondensed water vapor.

34. (Previously presented) The apparatus of claim 33 further comprising a condenser for condensing said carbon dioxide and a container for storing said carbon dioxide in liquid form.

35. (Previously presented) The apparatus of claim 33, wherein said extraction element comprises a membrane that is selectively permeable to hydrogen for extracting hydrogen from said conversion product, wherein said extraction element is operable to receive a feed of extraction gas downstream from said

permeable membrane, to lower the partial pressure of the hydrogen downstream from said permeable membrane and to dilute the flow of permeated hydrogen, thereby facilitating the permeation of the hydrogen and recovery of pure hydrogen through condensation of the extraction gas.

36. (Previously presented) The apparatus of claim 33, wherein said extraction element comprises a permeable membrane disposed inside said final conversion reactor, for lowering the partial pressure of the hydrogen during the conversion in said final conversion reactor, thereby promoting the conversion of the carbon monoxide into carbon dioxide.

37. (Previously presented) The apparatus of claim 36, wherein said final conversion reactor comprises a regulating device for regulating the temperature in said final reactor by acting on the flow rate and/or the input temperature of the extraction gas.

38. (Previously presented) The apparatus of claim 35, wherein said selectively permeable membrane is comprised of a plurality of tubes that descend into said extraction element, wherein each tube has the shape of a glove finger comprising an open end which opens to the outside of said extraction element to introduce said extraction gas into said tube.

39. (Previously presented) The apparatus of claim 32, wherein said heating device and said cooling heat exchanger are combined in a recovery exchanger so that said reagents and said conversion product circulate continuously through said recovery exchanger.

40. (Previously presented) The apparatus of claim 32, wherein said hydrogen extracted from said conversion product feeds a fuel cell running with air, and

further comprising an element for lowering the pressure of said conversion product and/or said hydrogen produced to compress the air required to run said fuel cell.

41. (Previously presented) The apparatus of claim 32, further comprising a hydrogen production unit for generating a flow of oxygen through an electrolyzer.

42. (Previously presented) The apparatus of claim 32, further comprising a nitrogen production unit for generating a flow of oxygen to limit the cost of producing the oxygen consumed in said apparatus.